

UNITED STATES PATENT APPLICATION

OF

SUK WON CHOI

AND

SU SEOK CHOI

FOR

**METHOD OF FABRICATING FERROELECTRIC LIQUID CRYSTAL
DISPLAY**

**LONG ALDRIDGE & NORMAN, LLP
701 PENNSYLVANIA AVENUE, N.W.
SIXTH FLOOR, SUITE 600
WASHINGTON, D.C. 20004
TEL: (202) 624-1200
FAX: (202) 624-1298**

[0001] This application claims the benefit of Korean Patent Application No. 2000-86964, filed on December 30, 2000, which is hereby incorporated by reference as if fully set forth herein.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] This invention relates to a method of fabricating a liquid crystal display, and more particularly to a method of fabricating a ferroelectric liquid crystal display that is capable of preventing inadequate injection of a liquid crystal.

Description of the Related Art

[0003] Generally, a liquid crystal display (LCD) includes a plurality of liquid crystal cells arranged in a matrix. Each liquid crystal cell changes a liquid crystal alignment state in accordance with an applied electric field to control the transmittance of light, thereby providing a gray scale.

[0004] A ferroelectric liquid crystal, among other liquid crystals utilized in liquid crystal displays, has the fastest response speed on the order of many microseconds (μ s) to a few milliseconds (ms), because ferroelectric liquid crystal material can polarize in the absence of an applied electric field. In addition, ferroelectric liquid crystal material can provide a wide viewing angle, for use in In-Plane Switching (IPS), without any special electrode structure or alignment film. Accordingly, the ferroelectric liquid crystal is capable of producing a motion picture display represented in a liquid crystal TV.

[0005] Generally, as temperature of the ferroelectric liquid crystal decreases, the

liquid crystal exhibits a phase-transition process as follows:

Isotropic Phase -> Chiral nematic (N*) phase -> Smectic C* (Sm C*) Phase ->
Crystal.

[0006] In such a phase-transition process, a ferroelectric liquid crystal display
5 utilizes the smectic phase, which is a ferroelectric liquid crystal phase that exists at a normal
(i.e. room) temperature.

[0007] The ferroelectric liquid crystal in the smectic phase is provided by injecting
and cooling the liquid crystal, which exhibits the isotropic phase or nematic phase. A
problem related to inadequate injection occurs because the volume of the liquid crystal
10 decreases upon its phase-transition to the smectic phase.

[0008] Fig. 1 is a figure briefly illustrating a liquid crystal injection device for
injecting the liquid crystal into a liquid crystal panel.

[0009] The liquid crystal injection device in Fig. 1 includes a chamber 12 and a
liquid crystal tray 16 which is located within the chamber and connected with an injection
15 hole 14 of a liquid crystal panel 10. Also, the liquid crystal injection device outside of the
chamber 12 further includes a heater (not shown) for heating and controlling the
temperature of the liquid crystal panel 10 and the liquid crystal tray 16, and a pressure
controller (not shown) controlling the inner pressure of the chamber 12. The transition
process of the liquid crystal to the desired ferroelectric liquid crystal phase using the
20 aforementioned liquid crystal injection device is as follows.

[0010] Firstly, in an exhaust process using the pressure controller, a vacuum state,
that is, a state of an equal pressure, is created inside of the chamber 12 and the liquid crystal

panel 10. Afterwards, the injection hole 14 of the liquid crystal panel then contacts the liquid crystal tray 16. At the same time, because the liquid crystal panel 10 and the chamber 12 remain in the vacuum state, the liquid crystal in the liquid crystal tray 16 is not injected into the liquid crystal panel 10. Subsequently, N₂ gas is injected into the chamber 12 using the pressure controller to make the inner pressure of the chamber 12 higher than the inner pressure of the liquid crystal panel 10. Due to such an inner pressure difference between the chamber 12 and the liquid crystal panel 10, the liquid crystal in the liquid crystal tray 16 is injected into the liquid crystal panel 10 through the injection hole 14. The difference in inner pressure between the chamber 12 and the liquid crystal panel 10 is increased, thereby easily injecting the liquid crystal into the liquid crystal panel 10. At the same time, the liquid crystal panel 10 and the liquid crystal tray 16 both sustain a high temperature, that is, sustain a liquid crystal injection temperature.

[0011] Next, the liquid crystal injected into the liquid crystal panel 10 and the liquid crystal panel 10 are cooled down under a certain pressure to make the liquid crystal undergo a phase transition from the isotropic phase or nematic phase to the smectic phase, which is a ferroelectric liquid crystal phase. Accordingly, the liquid crystal injected into the liquid crystal panel 10 experiences a volume decrease of around 3% upon its phase-transition to the smectic phase. As a result of this volumetric decrease, a problem related to inadequate injection of the liquid crystal occurs and a band configured perpendicular to the direction of the liquid crystal injection is formed where liquid crystal material is not injected.

SUMMARY OF THE INVENTION

[0012] Accordingly, the present invention is directed to a method of fabricating ferroelectric liquid crystal display that substantially obviates one or more of the problems due to limitations and disadvantages of the related art.

5 [0013] Accordingly, it is an advantage of the present invention to provide a method of fabricating a ferroelectric liquid crystal display that is capable of avoiding problems related to inadequate injection such as a decrease in volume of a cooled injected liquid crystal.

10 [0014] Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the structure particularly pointed out in the written description and claims hereof as well as the appended drawings.

15 [0015] In order to achieve these and other advantages of the invention, a method of fabricating the ferroelectric liquid crystal display according to one aspect of the present invention, comprises sustaining a pressure in a liquid crystal injected chamber at a first pressure while, at the same time, sustaining the temperature of a liquid crystal panel and a liquid crystal tray contacted to an injection hole thereof at a first temperature to inject the liquid crystal from the liquid crystal tray to the liquid crystal panel; increasing an inner
20 pressure of the chamber to a second pressure higher than the first pressure; and cooling down the liquid crystal panel and the chamber while sustaining the second pressure, and at the same time, maintaining the liquid crystal tray at the first temperature, thereby injecting the liquid crystal into a conventionally and previously un-injected portion of the liquid crystal panel.

25 [0016] The method, according to another aspect of the invention, further comprising

the step of, after the step of cooling the liquid crystal panel, decreasing the pressure of the chamber to a third pressure lower than the first pressure, and at the same time, cooling the liquid crystal tray down to a normal temperature.

[0017] Here, the first temperature is the temperature where the liquid crystal exhibits one liquid crystal phase comprising one of an isotropic phase and a nematic phase, and the liquid crystal panel is cooled down to the temperature where the injected liquid crystal exhibits the smectic phase.

[0018] A method of fabricating a ferroelectric liquid crystal display according to another aspect of the present invention comprises maintaining a pressure in a liquid crystal injected chamber at a first pressure, at the same time, maintaining the temperature of a liquid crystal panel and a liquid crystal tray contacted to an injection hole thereof at a first temperature, to inject the liquid crystal from the liquid crystal tray to the liquid crystal panel; slowly increasing the pressure of the chamber to a second pressure higher than the first pressure while cooling the liquid crystal panel, and at the same time, maintaining the liquid crystal tray at the first temperature to additionally inject the liquid crystal to a previously un-injected portion of the liquid crystal panel.

[0019] The method according to another aspect of the invention, further comprising, after cooling the liquid crystal panel, decreasing the pressure of the chamber to a third pressure lower than the first pressure, and at the same time, cooling the liquid crystal tray to a normal temperature.

[0020] The pressure in the chamber is increased from the first pressure to the second pressure corresponding to the cooling temperature of the liquid crystal panel or the pressure of the chamber is increased from the first pressure to the second pressure in step type fashion.

[0021] Presently, the first temperature is the temperature where the liquid crystal

exhibits one liquid crystal phase comprising one of an isotropic phase and a nematic phase, and the liquid crystal panel is cooled to the temperature where the injected liquid crystal exhibits the smectic phase.

[0022] A method of fabricating a ferroelectric liquid crystal display according to the other aspect of the present invention comprises maintaining a pressure in a liquid crystal injected chamber at a first pressure, at the same time, maintaining the temperature of a liquid crystal panel and a liquid crystal tray contacted to an injection hole thereof at a first temperature, to inject the liquid crystal from the liquid crystal tray to the liquid crystal panel; cooling the liquid crystal panel, and during its cooling period, repeatedly changing the pressure of the chamber from the first pressure to a second pressure, higher than the first pressure, and at the same time, maintaining the liquid crystal tray at the first temperature to inject the liquid crystal to a previously un-injected portion of the liquid crystal panel.

[0023] The method, according to another aspect of the invention, further comprises, after the step of cooling the liquid crystal panel, decreasing the pressure of the chamber decreased to a third pressure lower than the first pressure, and at the same time, cooling the liquid crystal tray to a normal temperature.

[0024] The pressure in the chamber is changed to repeat the cycle of rise-hold to the second pressure and drop-hold to the first pressure.

[0025] Here, the first temperature is the temperature where the liquid crystal exhibits one liquid crystal phase comprising one of an isotropic phase and a nematic phase, and the liquid crystal panel is cooled to the temperature where the injected liquid crystal exhibits the smectic phase.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description
5 serve to explain the principles of the invention.

[0027] In the drawings:

[0028] Fig. 1 is a plane figure briefly illustrating a conventional liquid crystal injection device.

[0029] Fig. 2A is a graph illustrating the characteristics of the change of a liquid
10 crystal panel temperature and a chamber pressure in accordance with time for a method of fabricating a ferroelectric liquid crystal display according to a first embodiment of the present invention.

[0030] Fig. 2B is a graph illustrating the characteristics of the change of a liquid
15 crystal tray temperature in accordance with time applied for a method of fabricating a ferroelectric liquid crystal display according to the first embodiment of the present invention.

[0031] Fig. 3A is a graph illustrating the characteristics of the change of a liquid
20 crystal panel temperature and a chamber pressure in accordance with time for a method of fabricating a ferroelectric liquid crystal display according to a second embodiment of the present invention.

[0032] Fig. 3B is a graph illustrating the characteristics of the change of a liquid
crystal tray temperature in accordance with the time for a method of fabricating a
ferroelectric liquid crystal display according to the second embodiment of the present
invention.

[0033] Fig. 4A is a graph illustrating the characteristics of the change of a liquid crystal panel temperature and a chamber pressure in accordance with time for a method of fabricating a ferroelectric liquid crystal display according to a third embodiment of the present invention.

5 [0034] Fig. 4B is a graph illustrating the characteristics of the change of a liquid crystal tray temperature in accordance with time for a method of fabricating a ferroelectric liquid crystal display according to the third embodiment of the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

10 [0035] Reference will now be made in detail to embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

15 [0036] Figs. 2A and 2B are graphic views illustrating the characteristics of change in the temperature and the pressure in a liquid crystal injection process of a method of fabricating a ferroelectric liquid crystal display according to a first embodiment of the present invention. Fig. 2A is a graph illustrating the characteristics of the changes in the pressure P in a chamber 12 and the temperature T in a liquid crystal panel 10 according to time t in a liquid crystal injection device as shown in Fig. 1. Fig. 2B is a graph illustrating the characteristics of the change in temperature of a liquid crystal in a liquid crystal tray 16.

20 [0037] Firstly, an injection hole 14 of the liquid crystal panel 10 is contacted to the liquid crystal tray 16 in the chamber 12, which is in a vacuum state. Then gas is injected into the chamber 12 to increase and sustain the pressure in the chamber 12 to a first pressure, that is, a liquid crystal injection pressure (e.g., about 2 atmospheres (atm)). At the same time, the liquid crystal panel 10 and the liquid crystal tray 16 are heated to sustain a liquid crystal injection temperature (i.e., 100°C). Accordingly, a liquid crystal in the isotropic

phase or nematic phase with a low viscosity in the liquid crystal tray 16 is injected into the liquid crystal panel 10 through the injection hole 14 because of the inner pressure difference between the chamber 12 and the liquid crystal panel 10.

[0038] After the liquid crystal in the isotropic phase or the nematic phase is injected under the sustained liquid injection pressure and temperature, the pressure in the chamber 12 is increased to a second pressure (X_{atm}) that is higher than the liquid crystal injection pressure just prior to cooling time (t_1) of the liquid crystal panel 10. The increased second pressure (X_{atm}) in the chamber 12 is made to remain constant during the period (t_2-t_1) while the liquid crystal panel 10 is cooled down from the liquid crystal injection temperature to a normal temperature at cooling time (t_1). The liquid crystal in the isotropic phase or nematic phase injected to the liquid crystal panel during the period (t_2-t_1) undergoes a phase-transition process to the smectic phase, which is a ferroelectric liquid crystal phase. As shown in Fig. 2B, as the liquid crystal in the liquid crystal panel is cooled to a normal temperature, the temperature of the liquid crystal tray 16 is maintained at the liquid crystal injection temperature (about 100°C).

[0039] In other words, the chamber 12 sustains the second pressure, which is higher than the liquid crystal injection pressure and the liquid crystal tray 16 sustains the liquid crystal injection temperature during the period (t_2-t_1), while the liquid crystal panel 10 is cooled. Accordingly, problems related to inadequate injection can be prevented because the liquid crystal is supplied to the previously un-injected portion of the liquid crystal panel 10, which is otherwise formed due to a decrease in the volume of the liquid crystal caused by the cooling of the liquid crystal panel 10.

[0040] The pressure in the chamber 12 is decreased to a third pressure (e.g., about 1_{atm}) that is lower than the liquid crystal injection pressure at the point of time(t_3) when these liquid crystal injection process is completed and the temperature of the liquid crystal

panel 10 is decreased to the normal temperature. As the pressure in the chamber 12 is decreased, the temperature of the liquid crystal tray 16 is decreased from the liquid crystal injection temperature to the normal temperature.

[0041] Figs. 3A and 3B are graphic views illustrating the characteristics of change in the temperature and the pressure in a liquid crystal injection process of a method of fabricating a ferroelectric liquid crystal display according to a second embodiment of the present invention. Fig. 3A is a graph illustrating the characteristics of the changes in the pressure P in a chamber 12 and the temperature T in a liquid crystal panel 10 according to time (t) in a liquid crystal injection device as shown in Fig. 1. Fig. 3B is a graph illustrating the characteristics of the change in the temperature of a liquid crystal in a liquid crystal tray 16.

[0042] Firstly, an injection hole 14 of the liquid crystal panel 10 is contacted to the liquid crystal tray 16 in the chamber 12, which is in a vacuum state. Then, gas is injected into the chamber 12 to increase and sustain the pressure in the chamber 12 to a first pressure, that is, a liquid crystal injection pressure (e.g., 2_{atm}). At the same time, the liquid crystal panel 10 and the liquid crystal tray 16 are heated to sustain a liquid crystal injection temperature (e.g., about 100°C). Accordingly, a liquid crystal in the isotropic phase or nematic phase with a low viscosity in the liquid crystal tray 16 is injected into the liquid crystal panel 10 through the injection hole 14 because of the inner pressure difference between the chamber 12 and the liquid crystal panel 10.

[0043] Thus, after the liquid crystal in the isotropic phase or the nematic phase is injected under the sustained liquid injection pressure and temperature, the pressure in the chamber 12 is made to slowly increase from the liquid crystal injection pressure at the point of the cooling time (t_1) of the liquid crystal panel 10. At this time, the pressure in the chamber 12 is made to slowly increase according to the cooling temperature of the liquid

crystal panel 10. For example, the pressure in the chamber 12 is increased from the liquid crystal injection pressure in step type fashion. The pressure in the chamber 12 is slowly increased to a second pressure (X_{atm}) that is higher than the liquid crystal injection pressure, during the period (t_2-t_1) while the liquid crystal panel 10 is cooled down from the liquid crystal injection temperature to a normal temperature. The liquid crystal in the isotropic phase or nematic phase injected to the liquid crystal panel during the cooling period (t_2-t_1) under goes a phase-transition process to the smectic phase. As the liquid crystal in the liquid crystal panel is cooled to a normal temperature, the liquid crystal tray 16 sustains the liquid crystal injection temperature (100°C).

[0044] In other words, the pressure in the chamber 12 slowly increases to the second pressure, which is higher than the liquid crystal injection pressure and the temperature of the liquid crystal tray 16 is sustained at the liquid crystal injection temperature during the period (t_2-t_1), while the liquid crystal panel 10 is cooled down. Accordingly, problems related to inadequate injection can be prevented because the liquid crystal is supplied to the previously un-injected portion of the liquid crystal panel 10, which is otherwise formed due to a decrease in the volume of the liquid crystal, caused by the cooling of the liquid crystal panel 10.

[0045] The pressure in the chamber 12 is decreased to a third pressure (i.e., 1_{atm}) lower than the liquid crystal injection pressure at the point of time (t_3) when these liquid crystal injection process is completed and the temperature of the liquid crystal panel 10 is decreased to the normal temperature. As the pressure in the chamber is decreased, the temperature of the liquid crystal tray 16 is dropped from the liquid crystal injection temperature to the normal temperature.

[0046] Figs. 4A and 4B are graphic views illustrating the characteristics of change in the temperature and the pressure in a liquid crystal injection process of a method of

fabricating a ferroelectric liquid crystal display according to a third embodiment of the present invention. Fig. 4A is a graph illustrating the characteristics of the changes in the pressure P in a chamber 12 and the temperature T in a liquid crystal panel 10 according to time (t) in a liquid crystal injection device as shown in Fig. 1. Fig. 4B is a graph illustrating the characteristics of the change in the temperature of a liquid crystal in a liquid crystal tray 16.

[0047] Firstly, an injection hole 14 of the liquid crystal panel 10 is contacted to the liquid crystal tray 16 in the chamber 12 which is in a vacuum state. Then, gas is injected into the chamber 12 to increase and sustain the pressure in the chamber 12 to a first pressure, that is, a liquid crystal injection pressure (e.g., about 2_{atm}). At the same time, the liquid crystal panel 10 and the liquid crystal tray 16 are heated to sustain a liquid crystal injection temperature (e.g., about 100°C). Accordingly, a liquid crystal in the isotropic phase or nematic phase with a low viscosity in the liquid crystal tray 16 is injected into the liquid crystal panel 10 through the injection hole 14 because of the inner pressure difference between the chamber 12 and the liquid crystal panel 10.

[0048] Thus, after the liquid crystal in the isotropic phase or the nematic phase is injected under the sustained liquid injection pressure temperature, the pressure in the chamber 12 is increased to a second pressure higher than the liquid crystal injection pressure at the point of the cooling time (t_1) of the liquid crystal panel 10. Subsequently, the pressure in the chamber 12 is repeatedly changed, for example, the pressure in the chamber 12 is increased to a second pressure (X_{atm}) for a certain time, then is made to drop to the liquid crystal injection pressure to remain for a certain time, and then is made to increase to the second pressure to remain for a certain time during the cooling period (t_2-t_1) of the liquid crystal panel 10. The liquid crystal in the isotropic phase or nematic phase under goes a phase-transition process to the smectic phase during the cooling period (t_2-t_1) of the liquid

crystal panel 10. At this moment, the liquid crystal tray 16 sustains the liquid crystal injection temperature(100°C).

[0049] In other words, during the period (t_2-t_1) while the liquid crystal panel 10 is cooled down, the pressure in the chamber 12 is made to repeat a rise-hold-drop-hold cycle to the pressure above the liquid crystal injection pressure, and the temperature of the liquid crystal tray 10 is sustained at the liquid crystal injection temperature. Accordingly, problems related to inadequate injection can be prevented because the liquid crystal is supplied to the previously un-injected portion of the liquid crystal panel 10 formed due to a decrease in the volume of the liquid crystal, caused by the cooling of the liquid crystal panel 10. Also, because the pressure in the chamber 12 repeats the rise-hold-drop-hold cycle, injection of the liquid crystal into the liquid crystal panel 10 can be made uniformly.

[0050] The pressure in the chamber 12 is repeatedly changed and is decreased to a third pressure (e.g., about 1_{atm}) that is lower than the liquid crystal injection pressure at the point of time (t_2) when the liquid crystal injection process is completed and the temperature of the liquid crystal panel 10 is dropped to the normal temperature. At the same time, the temperature of the liquid crystal tray 16 is decreased from the liquid crystal injection temperature to the normal temperature.

[0051] As described above, in the method of fabricating the ferroelectric liquid crystal display according to the present invention, the pressure in the chamber is made to be changed during the cooling period after the liquid crystal injection, and in addition, the temperature of the liquid crystal tray is maintained at the liquid crystal injection temperature to supply the liquid crystal to the previously un-injected portion of the liquid crystal panel 10, which is otherwise formed due to the volume shrinking of the liquid crystal, so that problems related to inadequate injection can be prevented.

[0052] It will be apparent to those skilled in the art that various modifications and variation can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and
5 their equivalents.